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Application of Fuzzy Multi-Criteria Decision Making Methods on Six Sigma Projects Selection

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Abstract. Six sigma method widely applied in production and service businesses is known as a project-oriented method. In six sigma method, selection of the prior project among others can be considered as a multi -criteria decision making problem. The conducted literature review has revealed that there is a large number of methods to select six sigma projects. It is more appropriate to use fuzzy multi-criteria decision making methods in project selection since evaluation criteria of six sigma projects include uncertainties. The aim of this study is to select the most appropriate project as a result of evaluating the projects by Fuzzy VIKOR, Fuzzy TOPSIS and Fuzzy COPRAS as methods of fuzzy multicriteria decision-making and integrating the ranking scores obtained from each method by Copeland method. The proposed method has been implemented in a large scale production company, operating in Aydın ASTİM Organized Industrial Zone.
Keywords. Six Sigma Projects, Fuzzy VIKOR, Fuzzy TOPSIS, Fuzzy COPRAS, Fuzzy AHP, Copeland Method.
JEL. M11, C44, L20, C02, D70, O22.

Highlights

* The decision-making process has transformed to an even more complex structure from the existence of humankind to the present day because of the multiplicity of options. In this direction, integration with fuzzy logic in order to maximize the contributing elements of the multi-criteria decision making techniques further increases the efficiency further in decision making. These are included in the literature as "fuzzy multi-criteria decision making techniques" and have been used in many studies.
* The purpose of this study was to select the most suitable project by using Copeland ordering method to integrate fuzzy VIKOR, fuzzy TOPSIS and fuzzy COPRAS methods, which are among the fuzzy multi-criteria decision making techniques, from six sigma projects. The evaluation of the projects could become possible with the aid of the criteria, which are the basis of the methods, and the weight of these criteria. In the literature, it is possible to find the studies that reveal the weights of criteria within the frame of fuzzy logic. In this study, the weights of the criteria were determined by using fuzzy AHP method and weights of the criteria obtained from the fuzzy AHP at the project evaluation stage were used in fuzzy VIKOR, fuzzy TOPSIS and fuzzy COPRAS.
* Each project was evaluated by verbal variables by the decision makers also taking the criteria into consideration. Verbal variables belonging to each decision maker were transformed into fuzzy triangular numbers, and then merging operation was performed by considering decision maker weights to form a single decision matrix. Thus, a single fuzzy decision matrix of all decision makers was obtained. The combined fuzzy decision matrix was evaluated by fuzzy VIKOR, fuzzy TOPSIS and fuzzy COPRAS method, and project

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orderings for each method were obtained separately. The integration of the orderings obtained from all three methods by using the Copeland method was provided and the six sigma project having the highest score in the new order was reported to the top management reporting that it should primarily be put into practice.

Summary

Many large-scale enterprises in the production and service sectors use six sigma as a process improvement method. Six sigma is a project-based method. For this reason, successful results can be obtained by focusing on the improvements for a single process. However, every six sigma project cannot achieve the desired success and there are numerous factors in this failure. The most important of these factors is the six sigma projects selected at the wrong time and without considering the priority order. The most important of these is the six sigma projects selected at the wrong time and without considering the priority order. Since the implementation of a project when it is not needed will cause high costs and the motivation loss of employees, the selection of the project to be considered primarily among the possible projects undertake a key role in success.

There are many evaluation and selection methods for six sigma project in the literature. Almost all of them evaluate six sigma projects with the assumption that certain information is obtained. However, it cannot provide a solution suggestion in cases where the project evaluation criteria are fuzzy. It may be more appropriate to use fuzzy logic, suggested by Zadeh (1965), in the evaluation phases of the projects since it is known to be closer to the approximate thinking style rather than thinking based on exact values. In addition, it was observed in numerous studies that the projects are evaluated in the framework of fuzzy logic and positive results are obtained.

In this study, since six sigma project evaluation criteria contain uncertainty, it has been found appropriate to use fuzzy logic and fuzzy multi-criteria decision making methods in project selection, which are the closest method to human thinking style. In the implementation work, it was aimed to evaluate the projects with the help of fuzzy multi criteria decision making techniques integrated with the Copeland method and to select the project that will provide the highest contribution to the enterprise.

In the implementation work, the selection of a large-scale company was important for the reliability of the study. Therefore, HAUS the company of centrifugal technologies located in Aydın ASTİM Organized Industrial Zone was selected. The long history, corporate and financial structure, and importance to quality studies of the company, and most importantly, its propensity for six sigma philosophy were also the reasons for selecting HAUS. HAUS company produces 11 kinds of products. The study was carried out on the 353 series decanters which are sold by company at most. The implementation work was carried out by following a three-step process.

The Phase of Determination of Decision-makers and Decision-Making Weights

The weights of decision makers in the study were determined by using fuzzy logic. Firstly, the Decision-Making Assessment Committee (DMAC) was established to determine and weight decision-makers. The committee members determined by the plant manager were determined as "Plant Manager", "Production Planning Manager" and "Human Resources Manager". From DMAC, each decision maker was asked to determine the influence level in the decisions by verbal variables. A triangular fuzzy decision matrix integrated from the membership functions determined by DMAC for each decision maker was obtained and the decision maker weights were obtained after the refinement and normalization processes. The weights of each decision maker were used in the phase of determining the criterion weights after this phase and in the project evaluation phase.

Determination Phase of Criteria and Criteria Weights

For the selection of six sigma projects, 15 criteria were determined as "Accessing to the Information", "Value Effect", "Financial Return", "Cost Reduction", "Employee Motivation", "Customer Satisfaction", "Learning and Development", "Measurability", "Project Cost", "Project Duration", "Sigma Level", "Eligibility", "Efficiency" and "Feasibility" in this study. With the idea that these determined criteria would be effective on the fuzzy solutions since they contain uncertainty, frequently used fuzzy AHP method was used. By using the extent analysis method, 15 criteria were evaluated by considering the weight of the decision makers. These obtained values were prepared to be used as weights of criteria in the evaluation of the projects with fuzzy TOPSIS, fuzzy VIKOR and fuzzy COPRAS methods.

Evaluation Phase of the Projects

After the interviews with 13 decision makers, it was concluded that 11 projects that will eliminate the main problems encountered in 353 series decanters should be put into practice. The projects considered to have low contribution were not included in the study. The projects were determined as; “Reducing Vibration Values ","Reduction of Noise Level ","Reduction of Rework Operations", "Increasing Product Performances", "Reduction of Electricity Consumption of the Product", "Removal of Spiral Errors", "Elimination of Balance Errors", "Improvement of Internal Logistics Activities", "Increasing the Production Capacity", "Reduction of Semi-Finished Stocks", and "Decreasing Set-Up Times".

The evaluation of the determined projects according to the criteria was also done with the help of verbal variables. For this, each decision maker expressed the effects of the projects on the criteria with the verbal variables of "very little", "little", " medium little ", "medium", "medium much", "much" and "very much"; then the fuzzy decision matrices of each decision maker were combined to be a single fuzzy matrix. The resultant combined fuzzy decision matrix was evaluated in fuzzy VIKOR, fuzzy TOPSIS and fuzzy COPRAS methods and different orderings were obtained in each method. The Copeland ordering method, which is included in the voting methods, was used to integrate the orderings obtained from all three methods as a single ordering. Thus, in the new ordering obtained as a result of the integration of the fuzzy VIKOR, fuzzy TOPSIS and fuzzy COPRAS methods, examined in this study, by using the Copeland method, it was concluded that the project "Reduction of Vibration Values" should be a priority project.

The presence of different calculations techniques for the fuzzy multi-criteria decision making methods in the literature may lead to obtain different results. From the methods examined in the study, the fuzzy VIKOR lists the alternatives by making comparisons according to the proximity measure to the ideal alternative. The fuzzy TOPSIS method lists the points that are the closest to the fuzzy positive ideal solution and the farthest to the fuzzy negative ideal solution. The fuzzy COPRAS method evaluates alternatives by listing them step by step in terms of importance and utility degrees.

As a result of the performed evaluations, it could be observed that the project orderings of all three methods were different. When the evaluation results were examined, it was found that while a decision maker who preferred fuzzy VIKOR or fuzzy COPRAS methods selected the "Reduction of Vibration Values " project, which was in the first place in the ordering; a decision maker who preferred the fuzzy TOPSIS method would choose the " Elimination of Balance Errors" project, which was in the first place in the ordering. Having different orders between methods causes decision makers to feel insecure about the methods. This situation pushes the decision maker to ask the question "which project should I choose by which method?" in addition to the question "which project should I choose?". To eliminate this anxiety, the advantages and disadvantages of fuzzy multi-criteria decision making methods were integrated into a single order by blending them with the Copeland ordering method. Thus, the orderings obtained by the integration of the methods with Copeland gave more confidence to the decision makers.

In this study, only three fuzzy multi-criteria decision making methods were examined because of time constraints and they were integrated with Copeland ordering method. Researchers will be able to obtain more different information and results by integrating more fuzzy multi-criteria decision-making methods with the Copeland ordering method in future studies.

References

Adams, C. W., Gupta, P. ve Wilson, C. E. (2003) *Six Sigma Deployment*, *Six Sigma Deployment*, Elsevier: ABD.

Akıllı, A., Atıl, H. ve Kesenkaş, H. (2014) Çiğ Süt Kalite Değerlendirmesinde Bulanık Mantık Yaklaşımı, *Kafkas Üniversitesi Veteriner Fakültesi Dergisi*, c. 20, s. 2, ss. 223–229.

Akpolat, H. (2004) *Six Sigma in Transactional and Service Environments*, Gower Publishing Limited: Burlington.

Aktaş, H. ve Çağman, N. (2005) Bulanık ve Yaklaşımlı Kümeler, *Çankaya Üniversitesi Fen-Edebiyat Fakültesi - Journal of Arts and Sciences*, c. 3, s. 1, ss. 13–25.

Akyüz, G. (2012) Bulanık VIKOR Yöntemi ile Tedarikçi Seçimi, *Atatürk Üniversitesi İktisadi ve İdari Bilimler Dergisi*, c. 26, s. 1, ss. 197–215.

Alavala, C. R. (2008) *Fuzzy Logic and Neural Networks - Basic Concepts and Applications*, New Age International Publishers: India.

Albayrak, B. (2009) *Proje Yönetimi ve Analizi*, Nobel Yayın Dağıtım: Ankara.

Alnıak, M. O. (2011) *Proje Yönetimi*, Beta Basım-Yayım Dağıtım A.Ş.: İstanbul.

Anbari, F. (2004) Success Factors in Managing Six Sigma Projects, *Proceedings of PMI Research*, ss. 1–14.

Antucheviciene, J., Zavadskas, E. K. ve Zakarevicius, A. (2012) Ranking Redevelopment Decisions of Derelict Buildings and Analysis of Ranking Results, *Economic Computation & Economic Cybernetics Studies & Research*, c. 46, s. 2.

Aplak, H. S. (2010) *Karar Verme Sürecinde Bulanık Mantık Bazlı Oyun Teorisi Uygulamaları*, (Yayımlanmamış doktora tezi), Gazi Üniversitesi Fen Bilimleri Enstitüsü: Ankara.

Aslan, D. ve Demir, S. (2005) Laboratuvar Tıbbında Altı-Sigma Kalite Yönetimi, *Türk Biyokimya Dergisi*, c. 30, s. 4, ss. 272–278.

Aytaç, E. (2011) *Kalite İyileştirme Sürecinde Bulanık Mantık Yaklaşımı ile Hata Türü ve Etkileri Analizi ve Uygulama Örneği*, (Yayımlanmamış doktora tezi), Adnan Menderes Üniversitesi Sosyal Bilimler Enstitüsü: Aydın.

Bañuelas, R., Tennant, C., Tuersley, I. ve Tang, S. (2006) Selection of Six Sigma Projects in the UK, *The TQM Magazine*, c. 18, s. 5, ss. 514–527.

Barutçugil, İ. (2008) *Proje Yönetimi*, Kariyer Developer: İstanbul.

Bass, I. (2007) *Six Sigma Statistics with Excel and Minitab*, The McGraw-Hill Companies: New York.

Baş, T. (2003) *Altı Sigma*, Kaliteofisi Yayınları: Ankara.

Başkaya, Z. (2011) *Bulanık Doğrusal Programlama*, Ekin Yayınevi: Bursa.

Baykal, N. ve Beyan, T. (2004a) *Bulanık Mantık - Uzman Sistemler ve Denetleyiciler*, Bıçaklar Kitabevi: Ankara.

Baykal, N. ve Beyan, T. (2004b) *Bulanık Mantık - İlke ve Temelleri*, Bıçaklar Kitabevi: Ankara.

Behara, R. S., Fontenot, G. F. ve Gresham, A. (1995) Customer Satisfaction Measurement and Analysis Using Six Sigma, *International Journal of Quality & Reliability Management*, c. 12, s. 3, ss. 9–18.

Bellman, R. E. ve Zadeh, L. A. (1970) Decision-Making in a Fuzzy Environment, *Management Science*, c. 17, s. 4, ss. 141–164.

Betsi, H. E. (2002) *Transactional Six Sigma and Lean Servicing - Leveraging Manufacturing Concepts to Achieve World-Class Service*, ST. Lucie Press: Florida.

Bilgen, B. ve Şen, M. (2012) Project Selection Through Fuzzy Analytic Hierarchy Process and a Case Study on Six Sigma Implementation in an Automotive Industry, *Production Planning & Control*, c. 23, s. 1, ss. 2–25.

Bojadziev, G. ve Bojadziev, M. (2007) *Fuzzy Logic for Business, Finance, and Management*, World Scientific Publishing Company: Singapore.

Breyfogle, F. W. (2003) *Implementing Six Sigma - Smarter Solutions Using Statistical Methods*, John Wiley & Sons: New York.

Breyfogle, F. W., Cupello, J. M. ve Meadows, B. (2001) *Managing Six Sigma: A Practical Guide to Understanding, Assessing, and Implementing the Strategy That Yields Bottom-Line Success*, John Wiley & Sons, Inc.: ABD.

Browne, C. (2013) *Pairwise Analysis*, http://www.youtube.com/watch?v= dhv6o9ubHC0, Erişim Tarihi: 18.10.2014.

Brue, G. (2002) *Six Sigma for Managers*, McGraw-Hill: New York.

Brue, G. (2006) *Six Sigma for Small Business*, Entrepreneur Media: Wisconsin.

Buckley, J. J. ve Eslami, E. (2002) *An Introduction to Fuzzy Logic and Fuzzy Sets (Advances in Intelligent and Soft Computing)*, Springer-Verlag: Heidelberg.

Büyüközkan, G. ve Öztürkcan, D. (2010) An Integrated Analytic Approach for Six Sigma Project Selection, *Expert Systems with Applications*, c. 37, s. 8, ss. 5835–5847.

Capital. (2003) *Six Sigma Zamanı*, http://www.capital.com.tr/liderlik/six-sigma-zamani-haberdetay-1338, Erişim Tarihi: 31.10.2014.

Chang, D. (1996) Applications of the Extent Analysis Method on Fuzzy AHP, *European Journal of Operational Research*, c. 2217, s. 95, ss. 649–655.

Chen, C.-T. (2000) Extensions of the TOPSIS for Group Decision-Making Under Fuzzy Environment, *Fuzzy Sets and Systems*, c. 114, s. 1, ss. 1–9.

Coronado, R. B. ve Antony, J. (2002) Critical Success Factors for the Successful Implementation of Six Sigma Projects in Organizations, *The TQM Magazine*, c. 14, s. 2, ss. 92–99.

Çakır, E. (2011) *Yalın Altı Sigma ve Bir Uygulama*, (Yayımlanmamış yüksek lisans tezi), Dokuz Eylül Üniversitesi Sosyal Bilimler Enstitüsü: İzmir.

Das, M. C., Sarkar, B. ve Ray, S. (2012) A Framework to Measure Relative Performance of Indian Technical Institutions Using Integrated Fuzzy AHP and COPRAS Methodology, *Socio-Economic Planning Sciences*, c. 46, s. 3, ss. 230–241.

David, J. ve Saaty, D. (2007) Use Analytic Hierarchy Process for Project Selection, *ASQ Six Sigma Forum Magazine*, c. August, ss. 22–29.

De Feo, J. ve Barnard, W. (2004) *Juran Institute's Six Sigma Breakthrough and Beyond- Quality Performance Methods*, McGraw-Hill: New York.

Demirci, H. (2008) *Toplam Kalite Yönetimi*, Kumsaati Yayın Dağıtım: İstanbul.

Dirgo, R. T. (2006) *Look Forward?: Beyond Lean and Six Sigma*, Aircraft Braking Systems Corporation.: ABD.

Doğruer, İ. M. (2007) *Proje Yönetimi*, Açılım Kitap: İstanbul.

Doğu, E. (2006) *Quality Function Deployment (QFD) And Using QFD in Six Sigma Projects*, (Yayımlanmamış yüksek lisans tezi), Dokuz Eylül Üniversitesi Sosyal Bilimler Enstitüsü: İzmir.

Dubois, D. ve Prade, H. (1980) *Fuzzy Sets and Systems: Theory and Applications*, Academic Press, Inc: ABD.

Eleren, A. ve Ersoy, M. (2007) Mermer Blok Kesim Yöntemlerinin Bulanık TOPSIS Yöntemiyle Değerlendirilmesi, *Madencilik*, c. 46, s. 3, ss. 9–22.

Elmas, Ç. (2003) *Bulanık Mantık Denetleyiciler - Kuram, Uygulama, Sinirsel Bulanık Mantık*, Seçkin Yayıncılık: Ankara.

Elmas, Ç. (2011) *Yapay Zeka Uygulamaları Yapay Sinir Ağları - Bulanık Mantık - Genetik Algoritma*, Seçkin Yayıncılık: Ankara.

Erdem, İ. (2013) *Yöneylem Araştırması ve WinQSB Uygulamaları*, Seçkin Yayıncılık: Ankara.

Erdem, S. ve Kavrukkoca, G. (2002) *Sürekli İyileştirme Projelerinin Seçiminde Analitik Hiyerarşi Süreci'nin Kullanımı*, http://www.deu.edu.tr/userweb/sabri.erdem/dosyalar/AHP.pdf, Erişim Tarihi: 17.08.2014.

Ertuğrul, İ. ve Karakaşoğlu, N. (2010) Electre ve Bulanık AHP Yöntemleri ile Bir İşletme için Bilgisayar Seçimi, *Dokuz Eylül Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, c. 25, s. 2, ss. 23–41.
Evans, J. R. ve Lindsay, W. M. (2005) *An Introduction to Six Sigma & Process Improvement*, Thomson/South-Western: ABD.
Firuzan, A. R. ve Kuvvetli, Ü. (2012) 1.5 Sigma Kaymanın İstatistiksel Nedenleri Üzerine Bir Araştırma, *Ekonometri ve İstatistik*, c. 16, ss. 1–11.
Fishburn, P. (1977) Condorcet Social Choice Functions, *SIAM Journal of Applied Mathematics*, c. 33, ss. 469–489.
Fouladgar, M. M., Yazdani-Chamzini, A., Lashgari, A., Zavadskas, E. K. ve Turskis, Z. (2012) Maintenance Strategy Selection Using AHP and COPRAS Under Fuzzy Environment, *International Journal of Strategic Property Management*, c. 16, s. 1, ss. 85–104.
Gavcar, E., Coşkun, E., Paksoy, T., Eleren, A., Sulak, H., Özdemir, M., … Keskin, R. (2011) *Yöneylem Araştırması*, (V. Tecim, Ed.), Lisans Yayıncılık: İstanbul.
George, M. L., Rowlands, D. ve Kastle, B. (2005) *Yalın Altı Sigma Nedir?*, SPAC Yayınları: Ankara.
Gotro, J. (2013) *The Two Key Criteria for Successful Six Sigma Project Selection*, http://www.innocentrix.com/files/wpsuccessfulsixsigmaprojectselection.pdf, Erişim Tarihi: 10.10.2014.
Gören, B. (2013) *Ağırlık Merkezi ve Alan Atalet Momenti*, İzmir.
Guiping, H., Lizhi, W., Bidanda, B. ve Fetch, S. (2007) Project Portfolio Selection for Implementing Lean and Six Sigma Concepts, *IIE Annual Conference and Expo 2007 - Industrial Engineering's Critical Role in a Flat World - Conference Proceedings* içinde , (ss. 1581–1586), ABD.
Gupta, P. (2004) *Six Sigma Business Scorecard, Perspectives on Performance*, The McGraw-Hill Companies: New York.
Gümüşoğlu, Ş. ve Tütek, H. H. (2008) *Sayısal Yöntemler Yönetsel Yaklaşım*, Beta Basım-Yayım Dağıtım A.Ş.: İstanbul.
Gürsakal, N. (2005) *Altı Sigma Müşteri Odaklı Yönetim*, Nobel Yayın Dağıtım: Bursa.
Gürsakal, N. ve Oğuzlar, A. (2003) *Altı Sigma*, Vipaş Yayınları: Bursa.
Hahn, G. J., Hill, W. J., Hoerl, R. W. ve Zinkgraf, S. A. (1999) The Impact of Six Sigma Improvement-A Glimpse Into the Future of Statistics, *American Statistical Association*, c. 53, s. 3, ss. 208–215.
Harry, M. ve Schroeder, R. (2000) *Six Sigma: The Breakthrough Management Strategy Revolutionizing the World's Top Corporations*, Doubleday: New York.
Haupt, S. E., Pasini, A. ve Marzban, C. (2008) *Artificial Intelligence Methods in the Environmental Sciences*, Springer Science+Business Media B.V: ABD.
Henderson, K. ve Evans, J. (2000) Successful Implementation of Six Sigma: Benchmarking General Electric Company, *Benchmarking: An International Journal*, c. 7, s. 4, ss. 260–281.
Hillier, F. S. ve Lieberman, G. J. (2001) *Introduction to Operational Research*, McGraw-Hill: New York.
Holpp, L. ve Pande, P. (2002) *What is Six Sigma?*, McGraw-Hill: ABD.
Hong, G. Y. ve Goh, T. N. (2003) Six Sigma in Software Quality, *The TQM Magazine*, c. 15, s. 6, ss. 364–373.
Hsieh, T.-Y., Lu, S.-T. ve Tzeng, G.-H. (2004) Fuzzy MCDM Approach for Planning and Design Tenders Selection in Public Office Buildings, *International Journal of Project Management*, c. 22, s. 7, ss. 573–584.
Hwang, C. L. ve Yoon, K. (1981) *Multiple Attribute Decision Making Methods and Applications*, Springer-Verlag: Berlin.
Ibrahim, A. M. (2004) *Endüstriye Dönük Uygulamalı: Gömülü Sistemlerle Bulanık Mantık*, Bileşim Yayınevi: Ankara.
İkiz, A. K. (2009) *Altı Sigma Projelerinin Değerlemesine Yeni Bir Yaklaşım: Reel Opsiyonlar*, (Yayımlanmamış doktora tezi), Dokuz Eylül Üniversitesi Sosyal Bilimler Enstitüsü: İzmir.
İnan, U. H. (2008) *Kalite Yönetim Sistemlerinde Tetkik Performansının Bulanık Mantık ile Analitik Hiyerarşi Süreci ve Bulanık Analitik Ağ Süreci Kullanılarak Ölçülmesi*, (Yayımlanmamış doktora tezi), Yıldız Teknik Üniversitesi Fen Bilimler Enstitüsü: İstanbul.
Işığıçok, E. (2011a) *Altı Sigma Kara Kuşaklar İçin Hipotez Testleri Yol Haritası*, Marmara Kitabevi: Bursa.
Işığıçok, E. (2011b) *100 Soruda Altı Sigma*, Marmara Kitabevi: Bursa.
Işığıçok, E. (2011c) *Ekonomiye - İş Dünyasına - Siyasete İstatistiksel Bakış*, Marmara Kitabevi: Bursa.
Işık, A. T. (2011) *Bütünleşik Üretim Planlamasında Bulanık Mantık Yaklaşımı ve Bir Uygulama*, (Yayımlanmamış doktora tezi), Adnan Menderes Üniversitesi Sosyal Bilimler Enstitüsü: Aydın.
Jain, M. (2008) *Delivering Successful Projects with TSP(SM) and Six Sigma*, Auerbach Publications.
Johnson, A. ve Swisher, B. (2003) How Six Sigma Improves R&D, *Research Technology Management*, c. 46, s. 2, ss. 12–15.
Kabalcı, E. (2013) Bulanık Mantığa Giriş, Nevşehir.
Kahraman, C. ve Büyüközkan, G. (2008) A Combined Fuzzy AHP and Fuzzy Goal Programming Approach for Effective Six-Sigma Project Selection, *J. of Mult.-Valued Logic & Soft Computing*, c. 14, ss. 599–615.
Kansoy, O. ve Dirgar, E. (2008) Altı Sigma Nedir, *e-Journal of New World Sciences Academy Qualitative Studies*, c. 4, s. 1, ss. 14–23.
Kaptanoğlu, D. ve Özok, A. F. (2010) Akademik Performans Değerlendirmesi için Bir Bulanık Model, *İTÜ Dergisi/d*, c. 5, s. 1, ss. 193–204.
Kasabov, N. K. (1998) *Foundations of Neural Networks, Fuzzy Systems, and Knowledge Engineering*, The MIT Press: London.
Kazemi, S. M., Karmasian, M., Homayouni, S. M. ve Vasili, M. R. (2012) Six Sigma Project Selections By Using A Fuzzy Multi Criteria Decision Making Approach: A Case Study In Poly Acryl Corp, *CIE42 Proceedings* içinde , (ss. 306–1 – 306–9), CIE & SAIIE: Cape Town, South Africa.
Kazemi, S. M., Kazemi, S. M. M. ve Bahri, M. (2005) Six Sigma Project Selections by Using a Multi Criteria Decision Making Approach: A Case Study in Poly Acryl Corp., *Proceedings of the 41st International Conference on Computers & Industrial Engineering* içinde , (ss. 502–507), ABD.
Keller, P. (2005) *Six Sigma Demystified*, McGraw-Hill: ABD.
Kelly, M. (2002) Three Steps to Project Selection, *ASQ Six Sigma Forum Magazine*, c. 2, s. 1, ss. 29–33.
Klamler, C. (2003) A Comparison of the Dodgson Method and the Copeland Rule, *Economics Bulletin*, c. 4, s. 8, ss. 1–7.
Klir, G. J. (2001) Foundations of Fuzzy Set Theory and Fuzzy Logic: a Historical Overview, *International Journal of General Systems*, c. 30, s. 2, ss. 91–132.
Kornfeld, B. ve Kara, S. (2013) Selection of Lean and Six Sigma Projects in Industry, *International Journal of Lean Six Sigma*, c. 4, s. 1, ss. 4–16.
Kumar, U. D., Crocker, J., Chitra, T. ve Saranga, H. (2006) *Reliability and Six Sigma*, *Reliability and Six Sigma*, Springer: New Jersey.
Kumar, U. D., Saranga, H., Ramírez-Márquez, J. E. ve Nowicki, D. (2007) Six Sigma Project Selection Using Data Envelopment Analysis, *The TQM Magazine*, c. 19, s. 5, ss. 419–441.
Larson, A. (2003) *Demystifying Six Sigma: A Company-Wide Approach to Continuous Improvement*, American Management Association: New York.
Levine, D. M. ve Gitlow, H. S. (2005) *Six Sigma for Green Belts and Champions*, Prentice Hall: ABD.
Lowenthal, J. N. (2002) *Six Sigma Project Management: A Pocket Guide*, ASQ Quality Press: Milwaukee.
Mamdani, E. H. ve Assilian, S. (1975) An Experiment in Linguistic Synthesis with a Fuzzy Logic Controller, *International Journal of Man-Machine Studies*, c. 7, ss. 1–13.
Mawby, W. D. (2007) *Project Portfolio Selection for Six Sigma*, ASQ Quality Press: ABD.
McCarty, T., Bremer, M., Daniels, L. ve Gupta, P. (2004) *The Six Sigma Black Belt Handbook*, McGraw-Hill: New York.
McDonald, M. (2013) *İş Süreçlerini İyileştirmek*, Optimist: İstanbul.
McNeill, F. M. ve Thro, E. (1994) *Fuzzy Logic: A Practical Approach*, Academic Press, Inc: London.
Meier, A. ve Donze, L. (2012) *Fuzzy Methods for Customer Relationship Management and Marketing: Applications and Classifications*, IGI Global: ABD.
Nabiyev, V. V. (2012) *Yapay Zeka*, Seçkin Yayıncılık: Ankara.

Naderi, H., Shahosseini, H. ve Jafari, A. (2013) Evaluation MCDM Multi-Disjoint Paths Selection Algorithms Using Fuzzy-Copeland Ranking Method, *International Journal of Communication Networks and Information Security*, c. 5, s. 1, ss. 59–67.
Naderi, S. H., Shams, P. ve Shahhoseini, H. S. (2012) Fuzzy-Copeland Ranking Method to Evaluate Multi-Disjoint Paths Selection Algorithms, *2012 IEEE 3rd International Conference* içinde , (ss. 761–764), Software Engineering and Service Science (ICSESS): Beijing.
Nguyen, H. T., Prasad, N. R., Walker, C. L. ve Walker, E. A. (2003) *A First Course in Fuzzy and Neural Control*, Chapman and Hall/CRC: Florida.
Opricovic, S. (2011) Fuzzy VIKOR with an Application to Water Resources Planning, *Expert Systems with Applications*, c. 38, s. 10, ss. 12983–12990.
Opricovic, S. ve Tzeng, G. H. (2004) Compromise Solution by MCDM Methods a Comparative Analysis of VIKOR and TOPSIS, *European Journal of Operational Research*, c. 156, s. 2, ss. 445–455.
Özdağoğlu, A. (2013a) İmalat İşletmeleri için Eksantrik Pres Alternatiflerinin COPRAS Yöntemi ile Karşılaştırılması, *Gümüşhane Üniversitesi Sosyal Bilimler Elektronik Dergisi*, c. 8, s. Haziran, ss. 1–22.
Özdağoğlu, A. (2013b) Çok Ölçütlü Karar Verme Modellerinde Normalizasyon Tekniklerinin Sonuçlara Etkisi : COPRAS Örneği, *Eskişehir Osmangazi Üniversitesi İİBF Dergisi*, c. 8, s. 2, ss. 229–252.
Özkan, M. M. (2003) *Bulanık Hedef Programlama*, Ekin Kitabevi: Bursa.
Öztürk, A. (2009) *Kalite Yönetimi ve Planlaması*, Ekin Kitabevi: Bursa.
Özveri, O. ve Çakır, E. (2012) Yalın Altı Sigma ve Bir Uygulama, *Afyon Kocatepe Üniversitesi, İİBF Dergisi*, c. 14, s. 2, ss. 17–36.
Özveri, O. ve Dinçel, D. (2012) Altı Sigma Proje Seçim Yöntemleri ve Bir Hastanede Uygulanması, *Dokuz Eylül Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, c. 27, s. 2, ss. 55–78.
Paksoy, T., Pehlivan, N. Y. ve Özceylan, E. (2013) *Bulanık Küme Teorisi*, Nobel Yayın: Ankara.
Pande, P., Neuman, R. ve Cavanagh, R. (2000) *The Six Sigma Way How GE, Motorola and Other Top Companies are Honing Their Performance*, McGraw-Hill: New York.
Pande, P., Neuman, R. ve Cavanagh, R. (2004) *Six Sigma Yolu Ge, Motorola ve Zirvedeki Diğer Firmaların Performanslarını Yükseltme Yöntemleri*, Klan Yayınları: İstanbul.
Patır, S. (2008) Kalite Anlayışında Altı Sigma Yaklaşımı, *Elektronik Sosyal Bilimler Dergisi*, c. 7, s. 24, ss. 63–83.
Pehlivan, N. Y. ve Apaydın, A. (2005) Bulanık k-En Yakın Komşuluk Tahmin Edicisi ve Bulanık Radyal Tabanlı Fonksiyon Ağları, *S.Ü Fen Ed. Fak. Fen Dergisi*, c. 26, ss. 19–32.
Polat, A., Cömert, B. ve Arıtürk, T. (2005) *Altı Sigma Vizyonu*, S.P.A.C. Altı Sigma Danışmanlık Ltd.Şti.: Ankara.
Portny, S. E. (2012) *Proje Yönetimi for Dummies*, Doğan Egmont Yayıncılık ve Yapımcılık Tic. A.Ş.: İstanbul.
Purjavad, E. ve Shirouyehzad, H. (2011) A MCDM Approach for Prioritizing Production Lines: A Case Study, *International Journal of Business and Management*, c. 6, s. 10, ss. 221–229.
Pyzdek, T. (2000a) *The Six Sigma Revolution*, *Quality America Inc*, ABD.
Pyzdek, T. (2000b, Eylül) Selecting Six Sigma Projects, *Quality Digest Magazine*, ss. 1–2.
Pyzdek, T. (2003) *The Six Sigma Project Planner: a Step-by-Step Guide to Leading a Six Sigma Project Through DMAIC*, McGraw-Hill: New York.
Pyzdek, T. ve Keller, P. A. (2010) *The Six Sigma Handbook A Complete Guide for Green Belts, Black Belts, and Managers at All Levels*, McGraw-Hill: New York.
Raisinghani, M. S., Ette, H., Pierce, R., Cannon, G. ve Daripaly, P. (2005) Six Sigma: Concepts, Tools, and Applications, *Industrial Management & Data Systems*, c. 105, s. 4, ss. 491–505.
Ray, S., Das, P., Bhattacharyay, B. K. ve Antony, J. (2013) Measuring Six Sigma Project Effectiveness using Fuzzy Approach, *Quality and Reliability Engineering International*, c. 29, s. 3, ss. 417–430.
Robometricschool. (2012) *The Basic Concepts of Fuzzy Logic*, *Robometricschool*, http://www.robometricschool.com/2012/12/the-basic-concepts-of-fuzzy-logic.html, Erişim Tarihi: 03.01.2015.
Roe, S. I. ve Ingle, S. (2001) Six Sigma Black Belt Implementation, *The TQM Magazine*, c. 13, s. 4, ss. 273–280.
Ross, T. J. (2010) *Fuzzy Logic with Engineering Applications*, Wiley Publishing: ABD.
Roth, H. ve Chen, C. (2005) *The Big Book of Six Sigma Training Games: Proven Ways to Teach Basic DMAIC Principles and Quality Improvement Tools*, McGraw-Hill Professional: ABD.
Saaty, T. ve Vargas, L. (2012) *Models, Methods, Concepts & Applications of the Analytic Hierarchy Process*, Springer: New York.
Saghaei, A. ve Didehkhani, H. (2011) Developing An Integrated Model for the Evaluation and Selection of Six Sigma Projects Based on ANFIS and Fuzzy Goal Programming, *Expert Systems with Applications*, c. 38, s. 1, ss. 721–728.
Sala, A. ve Albertos, P. (1998) Fuzzy Logic Controllers: Advantages and Drawbacks, R. Perez, M. Duarte ve G. Lefranc (Ed.), *Anales Volumen III* içinde , (ss. 833–844), IFAC: Valencia.
Sanver, M. R. (2000) Çoğunluk Yöntemi ve Condorcet Galipleri, *Ankara Üniversitesi SBF Dergisi*, c. 55, s. 3, ss. 133–144.
Sharma, U. (2003) Implementing Lean Principles With The Six Sigma Advantage: How A Battery Company Realized Significant Improvements, *Journal of Organizational Excellence*, c. 22, s. 3, ss. 43–52.
Sheehy, P., Navarro, D., Silvers, R., Keyes, V., Dixon, D. ve Picard, D. (2002) *The Black Belt Memory Jogger - A Pocket Guide for Six Sigma Success*, Six Sigma Academy: ABD.
Sheu, J.-B. (2004) A Hybrid Fuzzy-based Approach for Identifying Global Logistics Strategies, *Transportation Research Part E: Logistics and Transportation Review*, c. 40, s. 1, ss. 39–61.
Sivanandam, S. N., Sumathi, S. ve Deepa, S. N. (2007) *Introduction to Fuzzy Logic Using MATLAB*, Springer Berlin: Berlin.
Su, C. ve Chou, C. (2008) A Systematic Methodology for the Creation of Six Sigma Projects: A Case Study of Semiconductor Foundry, *Expert Systems with Applications*, c. 34, s. 4, ss. 2693–2703.
Şen, Z. (2003) *Modern Mantık*, Bilge Kültür Sanat: İstanbul.
Şen, Z. (2009) *Bulanık Mantık İlkeleri ve Modelleme*, Su Vakfı Yayınları: İstanbul.
Şentürk, Ö. (2013) *Six Sigma Project Evaluation Under Fuzziness in Food Industry*, (Yayımlanmamış yüksek lisans tezi), Kadir Has Üniversitesi Fen Bilimleri Enstitüsü: İstanbul.
Tanaka, K. (1997) *An Introduction to Fuzzy Logic for Practical Applications*, Springer: New York.
Taşkın, S. (2013) *Fizik Makaleleri: Heisenberg Belirsizlik İlkesi*, http://www.fizikmakaleleri.com/2013/02/heisenberg-belirsizlik-ilkesi.html, Erişim Tarihi: 21.08.2014.
Tekin, M. (2008) *Sayısal Yöntemler*, Selçuk Üniversitesi İİBF: Konya.
Teknomo, K. (2014) *Analytic Hierarchy Process (AHP) Tutorial*, http://web.cjcu.edu.tw/~lcc/Courses/TUTORIAL/AHP Tutorial.doc, Erişim Tarihi: 28.11.2014.
Tektaş, M. (2014) *Bulanık Mantık*, http://tektasi.net/wp-content/uploads/2014/01/Bulanik-Kumeler.pdf, Erişim Tarihi: 01.02.2015.
Thomsett, M. (2005) *Getting Started in Six Sigma*, John Wiley & Sons, Inc.: New Jersey.
Timor, M. (2010) *Yöneylem Araştırması*, Türkmen Kitabevi: İstanbul.
Timor, M. (2011) *Analitik Hiyerarşi Prosesi*, Türkmen Kitabevi: İstanbul.
Top, S. (2009) *Toplam Kalite Yönetimi Bağlamında Sürekli İyileştirme Anlayışı*, Beta Basım-Yayım Dağıtım A.Ş.: İstanbul.
Turan, A. H., Şenkayas, H. ve Başaloğlu, C. (2008) Altı Sigmanın Kobilerde Farkındalılığı, Ayırt Edici Faktörler ve Uygulama Karakteristikleri: Aydın İlinde Ampirik Bir Değerlendirme, *Afyon Kocatepe Üniversitesi, İ.İ.B.F. Dergisi*, c. X, s. II, ss. 57–78.
Ulucan, A. (2004) *Yöneylem Araştırması*, Siyasal Kitabevi: Ankara.
Westland, J. (2003) *Project Management Guideline*, Method123 Ltd.: ABD.
What Is Six Sigma? (2013)http://www.isixsigma.com/new-to-six-sigma/getting-started/what-six-sigma, Erişim Tarihi: 18.11.2014.

Wilson, M. P. (1999) *Six Sigma: Understanding the Concept, Implications and Challenges, Advanced System Consultants*, Advanced Systems Consultants: ABD.
www.haus.com.tr. (2014) HAUS Tanıtımı, Aydın.
Yang, T. Y. T. ve Hsieh, C. (2008) Six-Sigma Project Selection Using National Quality Award Criteria and Fuzzy Multiple Criteria Decision-Making Method, *Expert Systems with Applications*, c. 36, ss. 7594–7603.
Yaralıoğlu, K. (2015) *Bulanık Mantık*, http://www.deu.edu.tr/userweb/ k.yaralioglu/dosyalar/bul_man.doc, Erişim Tarihi: 04.01.2015.
Yazdani, M., Alidoosti, A. ve Zavadskas, E. K. (2011) Risk Analysis of Critical Infrastructures Using Fuzzy COPRAS, *Ekonomska Istrazivanja*, c. 24, s. 4, ss. 27–40.
Yıldırım, B. F. ve Önder, E. (2014) *İşletmeciler, Mühendisler ve Yöneticiler için Operasyonel, Yönetsel ve Stratejik Problemlerin Çözümünde Çok Kriterli Karar Verme Yöntemleri*, Dora Yayınları: Bursa.
Yıldız, A. (2014) *Proje Geliştirme/Planlama, Avrupa Birliği Genel Sekreterliği*, http://www.ua.gov.tr/docs/default-source/erasmus-/proje-planlama-ve-proje-yönetim-süreçleri-1.pdf?sfvrsn=0, Erişim Tarihi: 26.12.2014.
Young, T. L. (2007) *The Handbook of Project Management: A Practical Guide to Effective Policies, Techniques and Processes*, Kogan Page Publishers: ABD.
Yüksel, H. (2012) Evaluation of the Success of Six Sigma Projects by Data Envelopment Analysis, *International Journal of Business and Management*, c. 7, s. 13, ss. 75–84.
Zadeh, L. A. (1965) Fuzzy Sets, *Information and Control*, c. 8, ss. 338–353.
Zadeh, L. A. (1975) The Concept of a Linguistic Variable and its Application to Approxirqate Reasoning-I, *Information Sciences*, c. 8, ss. 199–249.
Zadeh, L. A. (1988) Fuzzy Logic, *Computer*, c. 21, s. 4, ss. 83–93.
Zadeh, L. A. (1994) Soft Computing and Fuzzy Logic, *Software, IEEE*, c. 48, s. November, ss. 48–56.
Zavadskas, E., Kaklauskas, A., Turskis, Z. ve Tamosaitiene, J. (2009) Multi-Attribute Decision-Making Model by Applying Grey Numbers, *Informatica*, c. 20, s. 2, ss. 305–320.
Zimmermann, H. J. (2001) *Fuzzy Set Theory and Its Applications*, Springer: Delhi.

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